Minimum Cost Matching for Autonomous Carsharing

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Motivation

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Carsharing

- Potential to reduce demand for vehicle ownership.
- Challenge of getting vehicles to users has limited growth.

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Autonomous vehicles can remove many of these limitations.

- Automatically move to users.
- Relocate to high demand areas.

Related Literature

Autonomous Mobility-On-Demand (AMoD) Systems

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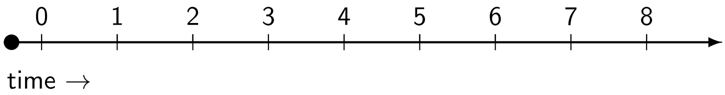
Taxi Dispatch Problem

- Assign taxis to users calling from different locations.
- Standard objective is to minimize taxi travel time and user wait time.

Problem Description



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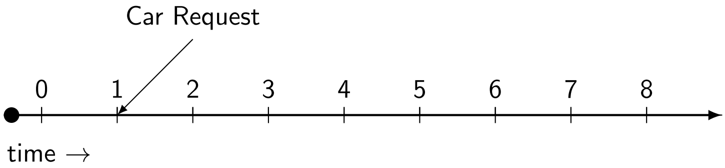

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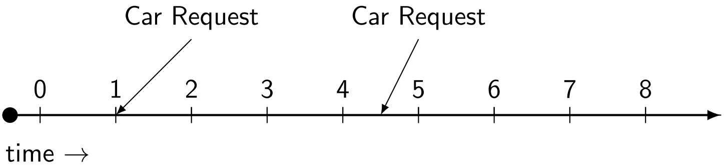

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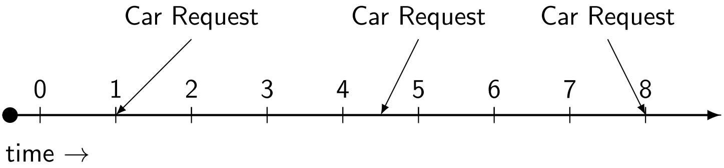

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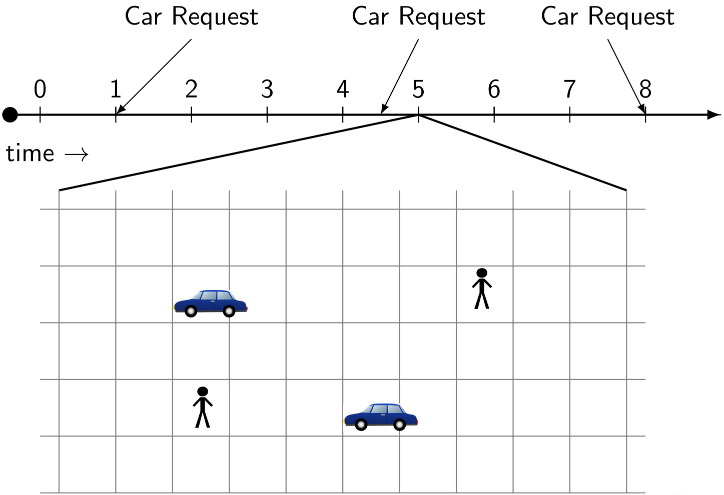

Notation

Formalized as a sequential bipartite graph matching problem.

- U_t - the set of user agents requesting a ride at time t.
- V_t - the set of vehicle agents available at time t.
- (u, v) is an assignment of vehicle $v \in V_t$ to user $u \in U_t$.
- ℓ_{uv} is the distance from u to v.

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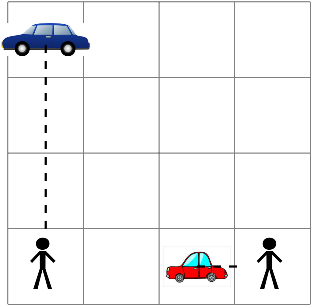
Strategic Manipulability

Find a set of assignments, M, such that $|M|$ is maximal and no user agent, u, has incentive to misreport their location to decrease ℓ_{uv}.

Baseline #1

Current carsharing systems use a first-come-first-serve assignment strategy:



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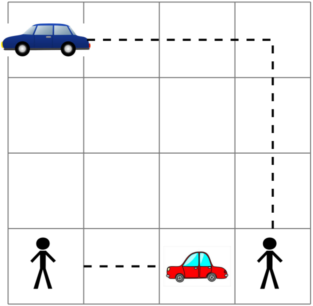
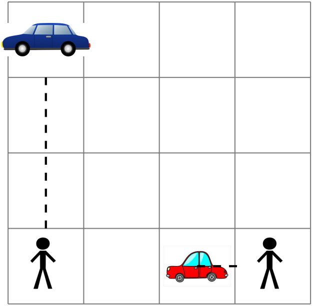


We refer to this method as the decentralized approach.

Baseline #2

Coordination can improve assignment:



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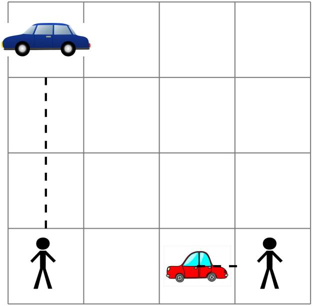
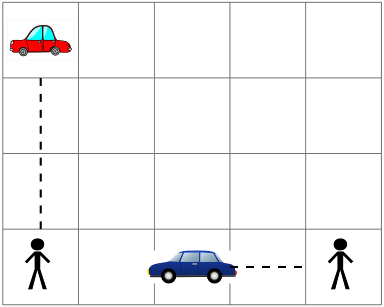


We refer to this method as the greedy approach.

Hungarian Algorithm

The optimal approach is the Hungarian algorithm[1] for minimum cost maximal matching.



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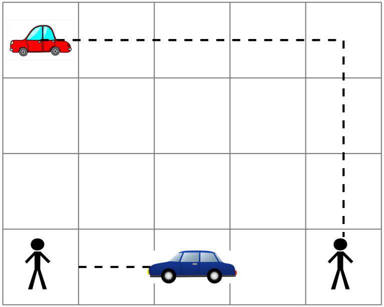

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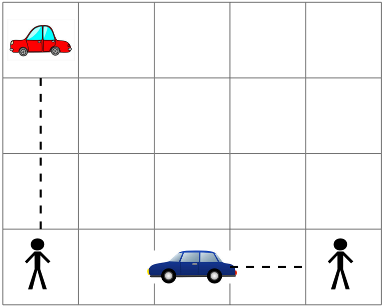

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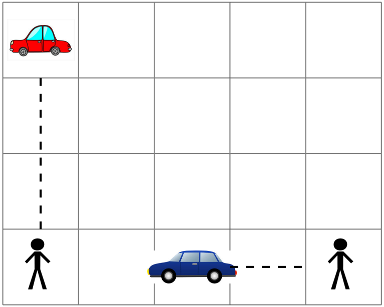

The Hungarian algorithm is optimal for our first objective.

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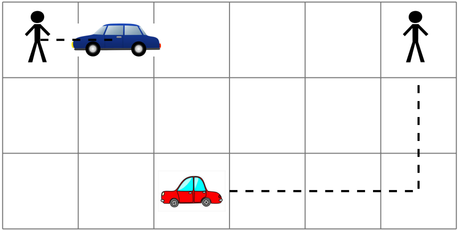
Minimal-makespan Algorithms

The Hungarian algorithm minimizes total distance at the expense of a subset of users who may experience long wait times.



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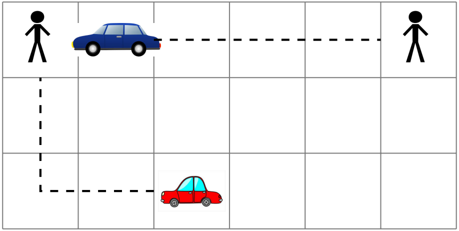
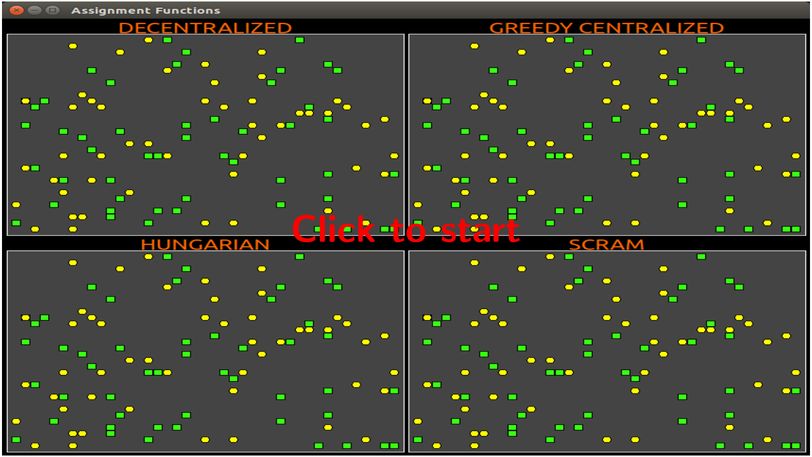


We minimize makespan with Scalable Collision-avoiding Role Assignment with Minimal Makespan (SCRAM) algorithms[2].

[2] Patrick MacAlpine, Eric Price, and Peter Stone. "SCRAM: Scalable Collision-avoiding Role Assignment with Minimal-makespan for Formational Positioning". In: *AAAI Conference on Artificial Intelligence (AAAI)*. 2015.


Assignment Functions
DECENTRALIZED
GREEDY CENTRALIZED
Click to start
HUNGARIAN
SCRAM

Simulated Empirical Studies

Empirical Analysis

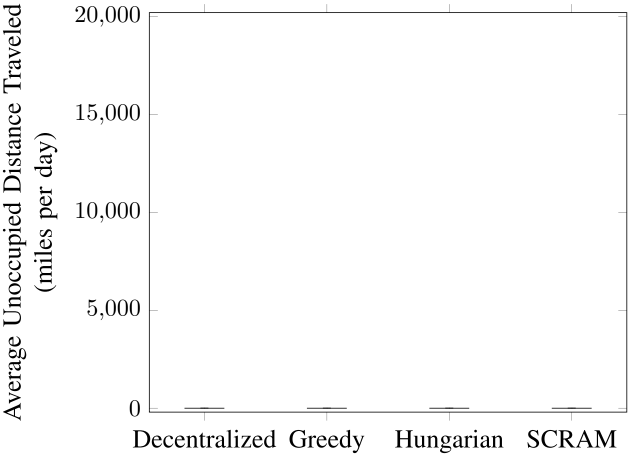
1. Minimum cost objective
2. Minimum makespan objective

Simulated model of carsharing[3].

- Simulate 50 days of carsharing operations in Austin, TX with each algorithm.
- Measure total unoccupied miles travelled.
- Measure wait time for every user.

[3] D. Fagnant and K.M. Kockelman. "The Travel and Environmental Implications of Shared Autonomous Vehicles, Using Agent-Based Model Scenarios". In: *Transportation Research Board Part C* 40 (2014), pp. 1–13.

Reduction in Distance Traveled



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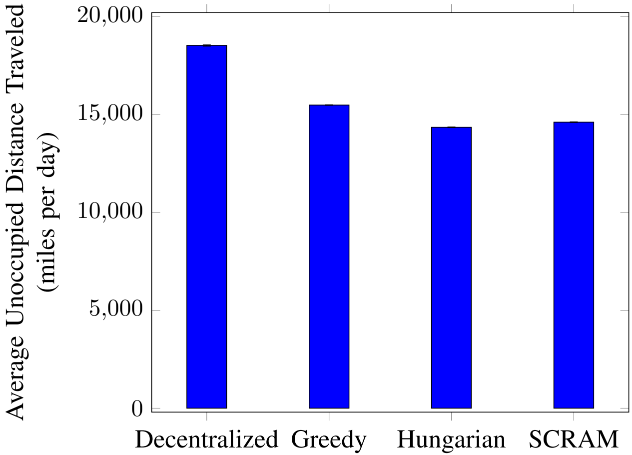
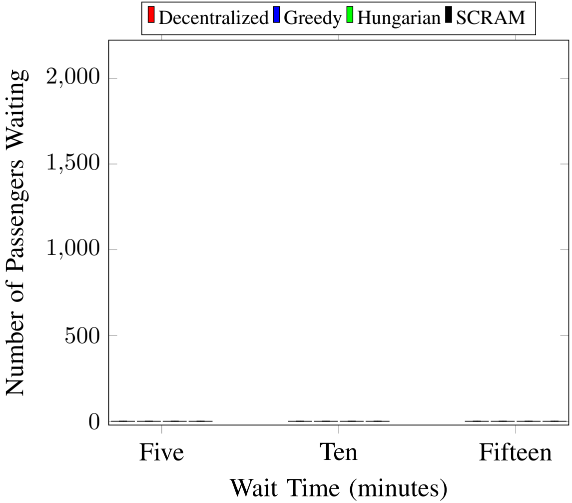


Reduction in Long Wait Times



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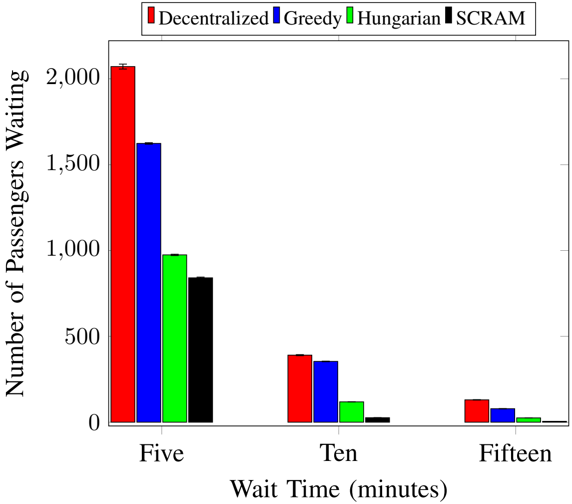
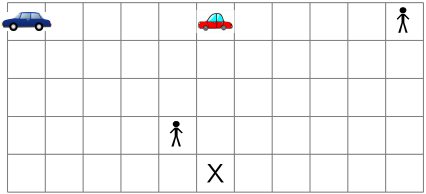


Strategic Manipulability

- More complex assignment strategies may be suboptimal for individual user agents.
- Introduces a motivation to manipulate the system.



Top user: 5, Bottom user: 7

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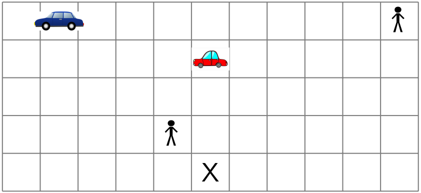

Top user: 6, Bottom user: 6

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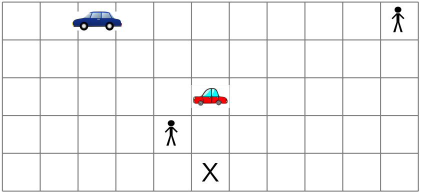

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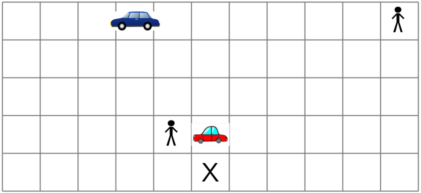

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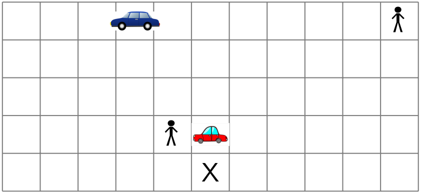

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We prove that setting a cancellation fee equal to Vickery-Clarkes-Groves (VCG) payments removes incentive to manipulate the system.

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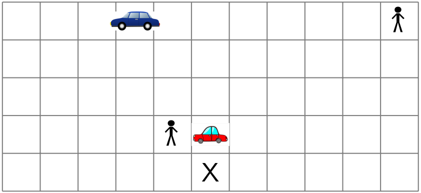

Top user: 7, Bottom user: ~~1~~ 8

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Conclusion

Contributions:

1. Analyzed methods for assigning vehicles in a carsharing system.
2. Presented a method that considers makespan of assignment.
3. Demonstrated and provided a solution to the problem of system manipulation.

Future Work:

1. Prediction of future demand.
2. Analyzing makespan and manipulability of taxi-dispatch algorithms.

Questions?